POLLINATION ECOLOGY OF *DURANTA REPENS* (VERBENACEAE)[1]

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(*With three text-figures*)

Key words: *Duranta repens,* butterflies, moth, *Macroglossum gyrans,* pollination

Duranta repens L. flowers chiefly during July-December. Anthesis is staggered round the clock and the flowers offer pollen and nectar as the reward to their insect visitors. The flowers are small and hermaphrodite. Nectar is secreted in measurable quantity on the first day, but only in traces on the second day. The nectar sugars are sucrose, glucose and fructose. Sucrose is predominant. Sugar concentration ranges from 12-21%. Protein and amino-acids too are present. The breeding system includes both geitonogamy and xenogamy.

A total of 30 diurnal insect species which are diurnal in their activity were found foraging at the flowers. The bees collected pollen as well as nectar from the flowers. Whereas the wasps, the butterflies and moths collected the nectar only. Heads of the bees and wasps, proboscids of the moths, proboscids and legs of the butterflies were seen touching the anther and stigmas thereby effecting pollination in the *D. repens.*

Introduction

Compared to bees the amount of research carried out in establishing butterflies' role in natural pollination is meagre. The dearth of information in the field of butterfly pollination was realised as early as 1949 by Verne Grant. Even then there are not many additions to the literature on butterfly pollination.

However, there are some studies highlighting the role of butterflies in the pollination of certain plants (Moldenke 1976, Cruden and Hermann-Parker 1979, Pajni and Sukhwinder Kaur 1979, Courtney *et al.* 1983, Bawa *et al.* 1983, Webb and Bawa 1983, Jennersten 1984, Subba Reddi & Meera Bai 1984, 1986; Meera Bai 1987, Byragi Reddy and Aruna 1990). These studies stressed the need to undertake detailed studies in different geographical regions to appreciate the role of butterflies in pollination.

The present paper deals with the interactions of *Duranta* and its pollinators in Visakhapatnam with special reference to butterflies.

Material and Methods

Duranta repens L. a hedge plant planted at Visakhapatnam (17° 42' N and 82° 18' E) was utilised for the study. Mature buds were identified based on the blue colour development on corolla. To record the anther dehiscence time: floral buds of different stages were slit open and observed with the help of a field macrolens of 10x magnification. Pollen output per anther was assessed by counting all the pollen grains in a sample obtained by gently crushing and tapping the anther on a clean microscope slide and spreading the pollen mass uniformly. Similarly, the pollen deposited on the stigmas were assessed at regular intervals. The inflorescences were bagged in the early hours (0500 hr) in order to have virgin flowers for controlled experiments. As and when the desired insect alone visited the virgin flower, the stigmas were immediately plucked and screened for the pollen loads. The longevity of pollen and stigma was assessed based on the fruit set success from hand-pollinations at regular intervals. The flowers to be hand-pollinated were emasculated in the bud condition. Test for apomixis/autogamy, geitonogamy, xenogamy were conducted through controlled pollinations. Apomixis was tested by bagging the emasculated flowers free of pollen, autogamy by pollinating flowers with the pollen of the same flower, for geitonogamy with the pollen of different flowers of conspecific plant, and for xenogamy with the pollen of the different conspecific plants.

Nectar produced in flowers protected from

[1]Accepted March 1994

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insects for a 3 hr period was measured using disposable micro-pipettes. Refractometer was used to determine nectar sugar concentration. Paper chromatography was used to determine nectar sugar composition (Harborne 1973). Amino acids and proteins were identified by the method of Baker and Baker (1973).

Insect foragers other than butterflies collected during the study period were identified through the courtesy of commonwealth Institute of Entomology, London and Zoological Survey of India, Calcutta. The butterflies caught over the flowers were identified with the help of Wynter-Blyth (1957). The nomenclature used is after Varshney (1983). The behaviour of visitors, the length of a visit and flowers visited in unit time using a stop watch were carefully studied. Four patches consisting of ten inflorescences each were marked at four study sites and visits were counted at half-an-hour intervals from 0600 to 1800 hours. The same procedure was repeated thrice on different dates. The more frequent visitors were caught and their bodies were examined under a stereomicroscope for the pollen adhering to body areas and then washed off with alcohol. The washings with a droplet of Lactophenol aniline-blue were observed for pollen under a light microscope.

Results

1. **Blooming phenology**: The plants flower chiefly during July-December in conjunction with monsoon rains. During the summer months of March-May the plants defoliate and are leafless. With rains from mid-June, vegetative growth begins. Inflorescences arise on the newly formed branches. When water is available, it is not uncommon to find plants in flower outside the normal flowering season.

The racemose inflorescence is both axillary and terminal. Its length varies from 5-15 cm, consequently the number of flowers it bears varies from 31-123. It blooms for 11-19 days. Flowers usually mature in basipetal succession. The number of flowers produced per day per inflorescence varies from 1-9 (av. 4.2) as indicated by the observations on ten inflorescences. The average pattern of flower production did not reveal any specific trend.

2. **Phenology of anthesis**: On any day during the flowering life of an inflorescence, there is no uniformity in the maturation and anthesis of flower buds. Buds were seen opening round the clock. On a clear sky day, a mature bud takes 20-30 minutes to open fully. The temperatures during anthesis on the day of observation ranged between 26.3 - 30°C and relative humidity between 89-77%.

3. **Pollen characters**: Anthers dehisce just prior to anthesis by longitudinal slits. Grains, spheroidal, 30-35 µm in diameter, tricolporate, exine smooth and cytoplasm granular. Their number per anther ranged from 950-1210 and averaged 1060. They retained viability for 12 hr from anther dehiscence as indicated by their capability to set fruit in controlled experiments. Grains stored for 4 hr gave 64% fruit set, those for 6 hr 48%, 8 hr 20%, 10 hr 12%, and 12 hr 4%. Thereafter, there was no fruit setting. Pollen-ovule ratio came to 1060 : 1.

4. **Stigma receptivity**: Stigma remained receptive for 24 hr beginning with anthesis. On hand-pollinations 6 hr old stigmata gave 68% fruit set, 9 hr old ones 56%, 12 hr old ones 48%, 15 hr old ones 28%, 18 hr old ones 24%, 24 hr old ones 16%, still older stigmata were not receptive.

5. **Flower life-time**: Corolla persisted for about 48 hr after anthesis and then fell off along with stamens. Flower visitor activity caused the corolla to fall even earlier by 3-5 hr.

6. **Nectar dynamics**: Flowers secreted nectar continuously from the time they opened until the corolla dropped off. Nectar was secreted in measurable quantity on the first day, but it was negligible on the second day. Measurements at 3 hr intervals ranged from 0.3-1.0 µl. Sugar concentration ranged from 12-21%. Sucrose, glucose and fructose were present, the former being dominant. Proteins and amino acids were present; histidine scale was 4.0.

7. **Flower-visitor activity dynamics**: i) *Composition and abundance*: A total of 30 insect species foraged at the flowers (Table 1). Of these 11 are Hymenoptera (Apidae 3, Xylocopidae 2, Anthophoridae 4, Megachilidae 1, and Vespidae 1),

TABLE 1
PARTICULARS OF FLOWER-VISITORS ON
Duranta repens

Visitor species	Forage type: Pollen	Forage type: Nectar	Body region of pollen deposition
HYMENOPTERA			
APIDAE			
Apis cerana indica	+	—	Head, Proboscis
A. florea	+	—	"
Trigona sp.	+	—	"
ANTHOPHORIDAE			
Amegilla sp.	+	+	"
Ceratina sp.	+	—	"
Thyreus histrio	+	—	"
Pithitis binghami	+	—	"
XYLOCOPIDAE			
Xylocopa latipes	+	+	"
X. pubescens	+	+	"
MEGACHILIDAE			
Megachile sp.	+	—	"
VESPIDAE			
Ropalidia spatulata	—	+	"
LEPIDOPTERA			
SPHINGIDAE			
Macroglossum gyrans	—	+	Proboscis
DANAIDAE			
Danaus chrysippus	—	+	Proboscis, legs
Euploea core	—	+	"
NYMPHALIDAE			
Euthalia garuda	—	+	"
Hypolimnas misippus	—	+	"
Precis lemonias	—	+	"
P. hierta	—	+	"
Phalanta phalantha	—	+	"
ACRACIDAE			
Acraea violae	—	+	"
PAPILIONIDAE			
Atrophaneura hector	—	+	"
Papilio polytes romulus	—	+	"
P. demoleus	—	+	"
Graphium agamemnon	—	+	"
PIERIDAE			
Cephora nerissa	—	+	"
Catopsilia crocale pomona	—	+	"
C. pyranthe	—	+	"
HESPERIIDAE			
Barbo cinnara	—	+	"
Pelopidas mathias	—	+	"

and the others Lepidoptera (1 Sphingid moth, 2 Danaids, 4 Nymphalids, 1 Acraeid, 4 Papilionids, 4 Pierids and 2 Hesperids). Apart from these flower visitors, a floriphagous beetle (*Mylabris pustulata*) was also observed. Lizards and spiders were seen waiting near the flowers to prey on the flower visiting butterflies and bees.

All the 30 species were not common to all the study sites (Table 2). Thus *Apis cerana indica, Amegilla* sp., *Thyreus histrio, Xylocopa* sp., *Macroglossum gyrans, Danaus chrysippus, Precis lemonias, Atrophaneura hector, Papilio polytes, Graphium agamemnon, Catopsilia pyranthe, Catopsilia crocale pomona, Barbo cinnara* and *Pelopidas mathias* were common to all the study sites. More constant and abundant of these visitors were *Apis cerana indica, Amegilla* sp., *M. gyrans, D. chrysippus, P. polytes, G. agamemnon, A. hector, C. pyranthe* and *C.c. pomona.*

Of the four groups of visitors, namely butterflies, bees, hawkmoths and wasps, the former dominated and their visits made up 49.75% of the total visits. Bees accounted for 34.75%, hawkmoth 14.5% and wasps 1.0%. At each of the four study sites, the same order of frequency of visits by different insect groups prevailed, of course, while their actual percentage of visits varied (Fig. 1).

ii) *Diurnal activity*: All the visitors listed in Table 2 are diurnal in their activity, and visited the flowers during 0600-1800 hr. Individual foragers exhibited peak activity in certain hours. On fine weather days *M. gyrans* exhibited stratification, visiting the flowers during two specified periods from 0600-0800 hr and again from 1600-1800 hr. But on cloudy days the visits were uniformly distributed over 0600-1800 hr. Thus the wild bee *Amegilla* sp. was more frequent during 0900-1300 hr, *A.c. indica* during 0900-1300 hr, *C.c. pomona* during 0800-1300 hr, *C. pyranthe* during 0900-1500 hr, *G. agamemnon* during 0800-1200 hr, *P. polytes* during 0600-0900 hr. and *A. hector* during 0600-1000 hr.

iii) *Flower visits per unit time and length of a visit*: Table 3 gives the data concerning length of a visit and total flowers visited per minute by different flower visitors. *M. gyrans, Amegilla* sp., *G.*

TABLE 2
CENSUS OF FLOWER VISITORS ON *D. repens* IN 1986 SEASON

	Site I			Site II			Site III			Site IV		
Insect species	18/7	28/7	1/9	14/7	26/7	31/8	16/7	29/7	3/9	10/10	25/10	3/11
BEES												
Apis cerana indica	315	439	114	299	486	209	845	919	436	66	216	314
A. florea	0	176	67	0	117	0	0	667	0	0	0	0
Ceratina sp.	42	102	0	0	0	0	109	159	771	98	205	0
Trigona sp.	0	0	0	73	80	20	0	0	0	0	0	72
Amegilla sp.	556	874	938	618	1,008	689	1,178	1,325	690	344	862	1,060
Thyreus histrio	0	152	238	0	64	60	239	340	186	0	197	0
Pithitis binghami	0	0	8	19	32	0	0	0	0	184	229	0
Xylocopa latipes	108	0	36	0	128	230	0	50	143	576	619	432
X. pubescens	0	0	0	0	110	192	0	78	98	457	603	512
Megachile sp.	0	185	340	0	0	186	0	0	0	163	205	0
WASP												
Ropalidia spatulata	25	38	77	29	44	162	0	51	30	0	0	0
MOTH												
Macroglossum gyrans	1,058	876	1,628	456	778	721	765	1,360	514	1,086	478	833
BUTTERFLIES												
Danaus chrysippus	367	89	7	155	67	78	111	131	87	11	84	234
Euploea core	0	141	0	62	44	61	71	142	69	0	0	0
Euthalia garuda	186	313	62	146	145	0	0	0	225	0	0	0
Hypolimnas misippus	0	0	23	0	0	20	0	0	0	36	52	0
Precis lemonias	126	0	0	83	71	37	0	201	0	11	0	198
P. hierta	19	27	0	22	20	0	0	0	0	0	0	0
Phalanta phalantha	0	46	0	60	0	47	0	0	0	0	0	0
Acraea violae	0	0	0	0	249	19	0	0	0	0	0	0
Atrophaneura hector	743	0	0	0	0	46	383	725	318	618	477	755
Papilio polytes romulus	716	428	248	307	546	402	422	562	290	97	254	658
P. demoleus	30	0	0	0	0	0	0	0	0	80	111	0
Graphium agamemnon	766	679	359	460	463	698	666	887	301	267	495	721
Cephora nerissa	63	0	34	0	116	0	0	0	0	0	0	0
Catopsilia pyranthe	631	760	131	609	931	783	496	630	487	187	574	972
C. crocale pomona	572	592	74	564	652	555	718	765	520	152	493	765
Eurema hecabe	0	214	0	73	103	0	59	0	49	0	0	0
Barbo cinnara	0	0	13	0	0	94	0	104	0	151	225	176
Pelopidas mathias	255	104	0	0	99	0	248	0	139	0	55	294
Total visits	6,578	6,235	4,397	4,035	6,353	5,309	6,310	9,096	5,353	4,594	6,434	7,996

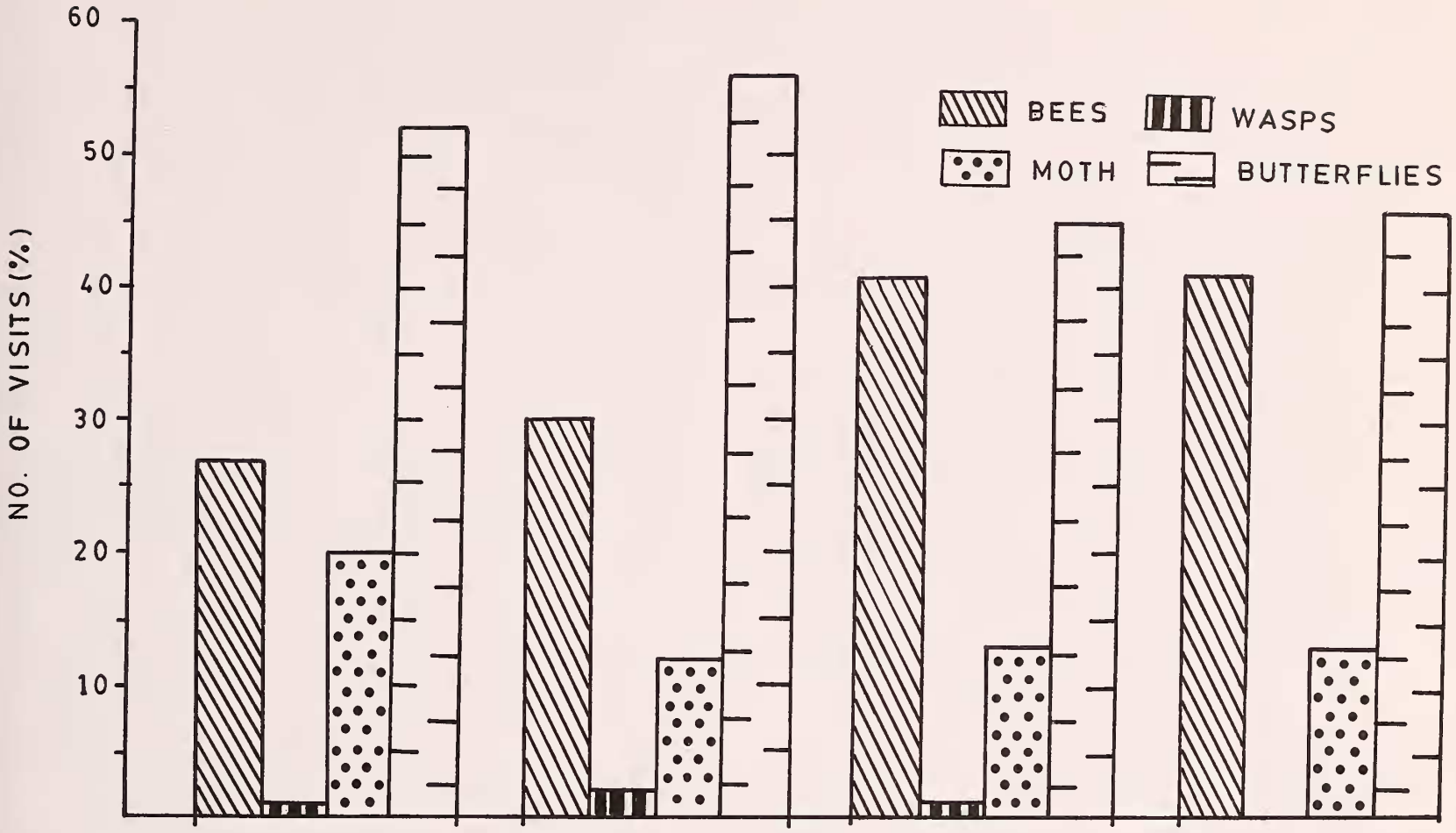

Fig. 1. Insect group abundance on *D. repens* flowers at different study sites.

agamemnon, P. polytes, and *A. hector* spent relatively less time at each flower and consequently covered a large number of flowers in unit time.

iv) *Insect behaviour at flowers*: The bees landed on corolla rim and probed for nectar. Then their head region touched the anthers. From the visual observations it was evident that the pollen collection and nectar gathering were not done in the same bout. *Amegilla* discriminated new from old flowers and visited mostly fresh flowers. *M. gyrans* while collecting nectar hovered at the flower, and probed the flowers in rapid succession. The butterflies were seen landing on the inflorescence for foraging. The papilionids characteristically fluttered while foraging. The proboscis and legs contacted the anthers and stigmas.

v) *Pollen transfer in the first visit by various visitors*: The amount of pollen removed from anthers and transfered to stigma in the first visit varied with different insect species. Of the 12 species for which such data were collected (Table 4), the efficiency order is descending from *Xylocopa, Amegilla, A.c. indica, P. polytes, G. agamemnon, A. hector* and *M. gyrans,* etc.

vi) *Pollen in body-washings of various flower visitors*: Of the nine species for which such data were collected, *Amegilla, Apis cerana indica, T. histrio, Ceratina* sp., and *P. polytes* carried relatively a larger number of pollen on their bodies (Table 5).

vii) *Pollen depletion from anthers vs. pollen deposition on stigmata under foragers activity*: Pollen-deposition could be related to pollen-depletion. During 0800-1200 hr there was 74% of pollen removal. In the same period pollen deposition was also high (Table 6). Both these events could be positively related to foragers activity which was high during this period.

viii) *Pollen loads on stigmata under lepidopteran activity*: Figures 2 and 3 give the

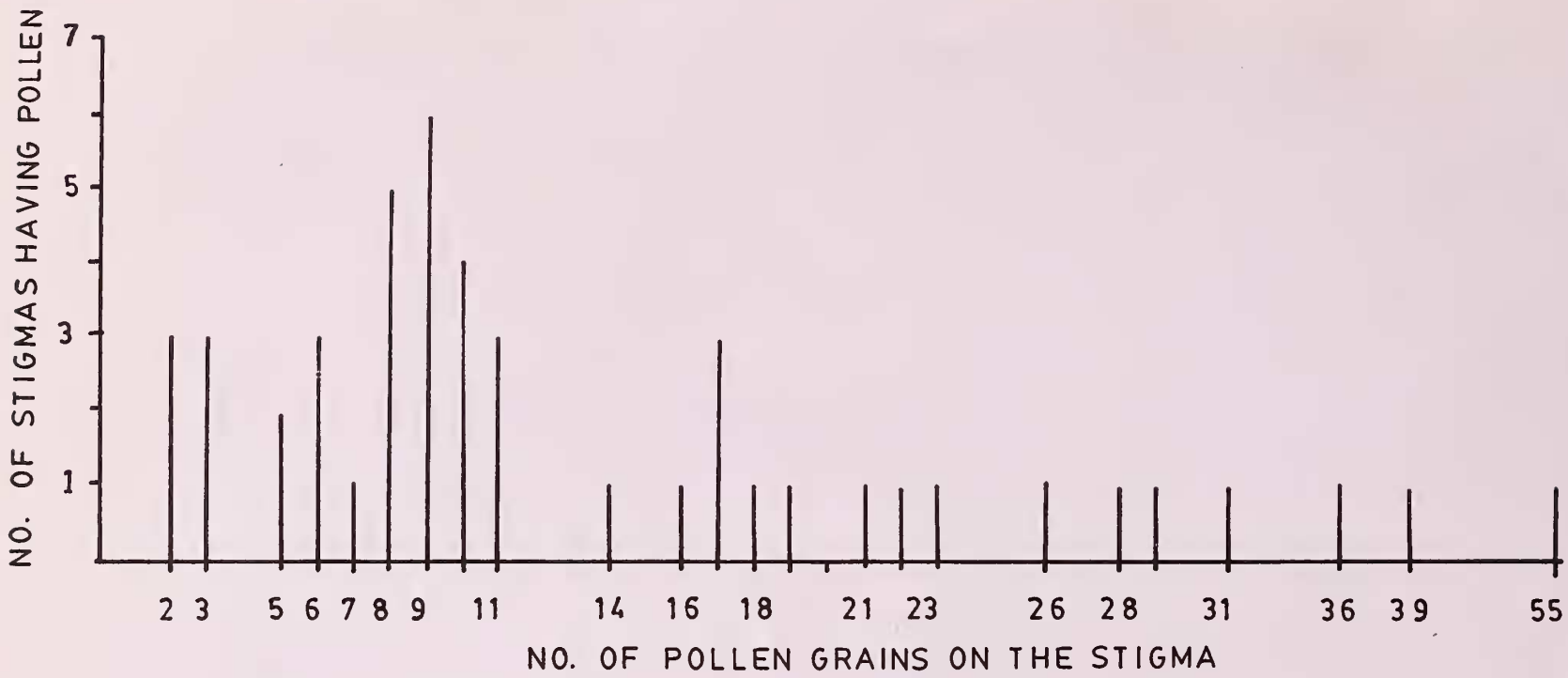

Fig. 2. Histogram diagram showing the frequency of stigmas having different number of pollen grains after hawkmoth visits.

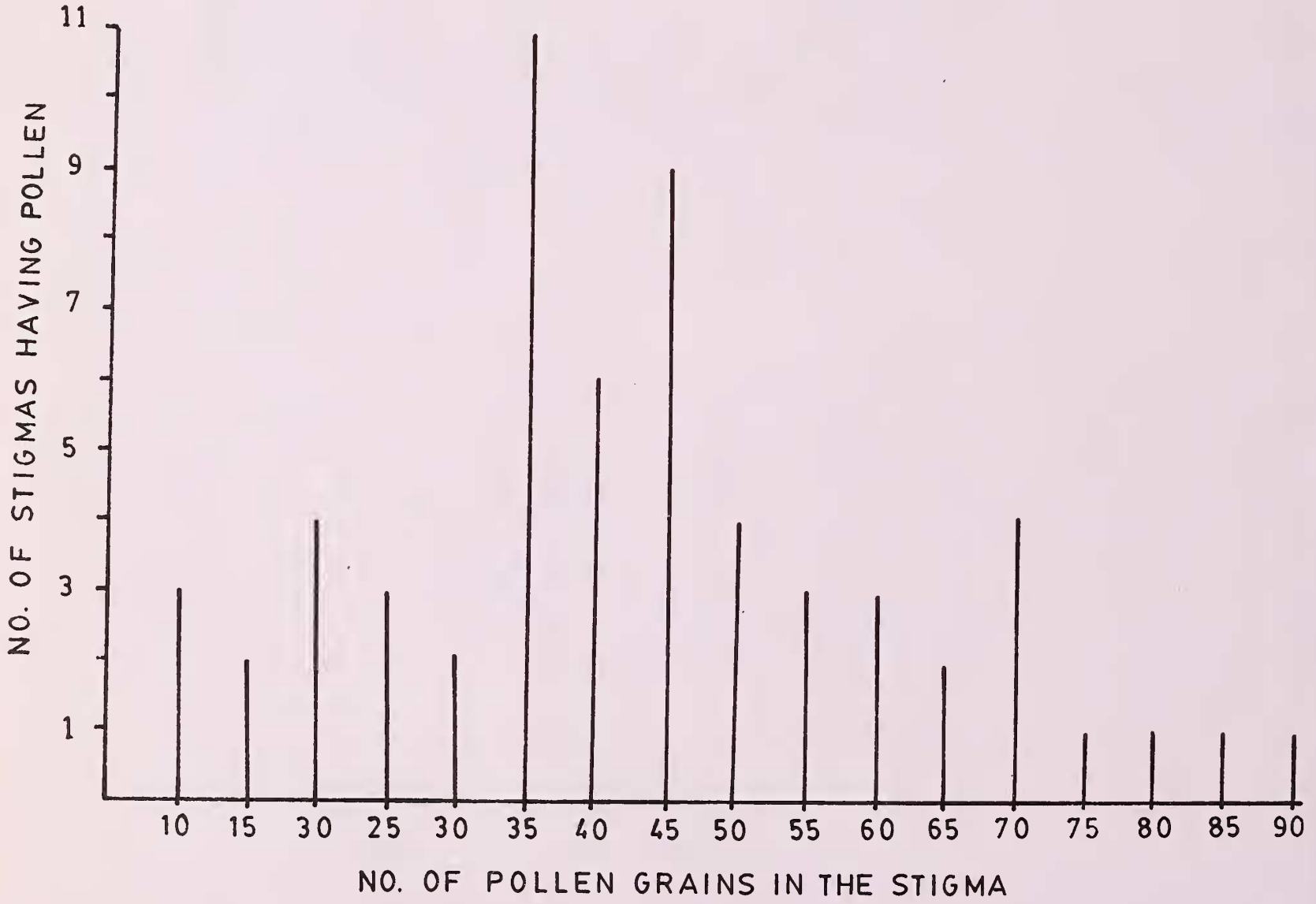

Fig. 3. Histogram diagram showing the frequency of stigmas having different number of pollen grains after butterfly visits.

TABLE 3
LENGTH OF A VISIT OF FORAGERS ON *Duranta repens* AND NUMBER OF VISITS IN UNIT TIME

Flower visitor	Sample size	Length of a visit in seconds		No. of flowers visited/minute	
		Range	Mean	Range	Mean
Apis cerana indica	5	2-5	4.0	13-27	15.0
A. florea	5	2-6	4.5	12-30	20.5
Ceratina sp.	5	2-7	5.0	12-23	17.0
Trigona sp.	5	3-5	4.0	17-23	19.0
Amegilla sp.	5	2-4	3.9	26-35	31.0
Thyreus histrio	5	2-7	5.5	12-22	20.0
Xylocopa latipes	5	7-12	9.0	5-10	7.0
X. pubescens	5	5-12	8.5	6-14	8.0
Ropalidia spatulata	5	1-3	2.5	37-49	42.0
Macroglossum gyrans	5	1-2	1.5	42-74	57.0
Danaus chrysippus	5	6-12	8.0	6-13	9.0
Euthalia garnda	5	7-20	13.5	10-20	16.0
Precis lemonias	5	3-14	7.0	3-9	6.0
P. hierta	5	3-12	6.0	5-20	13.0
Phalanta phalantha	5	6-14	9.0	8-13	10.0
Acraea violae	5	2-5	3.5	14-20	17.5
Atrophaneura hector	5	3-6	5.0	10-30	20.0
Papilio polytes romulus	5	3-9	4.0	6-20	13.0
Graphium agamemnon	5	1-5	2.0	36-52	40.0
Cephora nerissa	5	5-10	8.0	10-20	10.0
Catopsilia crocale pomona	5	4-8	6.0	5-15	8.0
C. pyranthe	5	4-9	6.0	4-15	8.0
Eurema hecabe	5	4-12	7.0	6-14	9.0

TABLE 4
POLLEN DEPLETION FROM ANTHERS *vs.* POLLEN DEPOSITION ON STIGMAS IN FIRST VISIT OF SOME FORAGERS ON *D. repens*

Name of the visitor	Mean no. of Pollen/flower after 1st visit	Pollen depletion (%)	Mean no. of pollen/stigma after 1st visit	Pollen deposition (%)
Apis cerana indica	3160	25	26	8
A. florea	3290	22	19	6
Amegilla sp.	2810	34	31	10
Thyreus histrio	3010	29	19	6
Xylocopa latipes	2410	43	52	16
X. pubescens	2200	48	61	20
Macroglossum gyrans	3710	13	23	6
Danans chrysippus	4000	5	4	1
Atrophaneura hector	2540	16	21	6
Papilio p. romulus	3410	19	25	8
Graphium agamemnon	3610	15	24	8
Catopsilia c. pomona	3800	10	11	3
C. pyranthe	3920	7	8	2

Average number of pollen produced per flower = 4240.
Number of flowers sampled = 10.

number of pollen grains deposited on the stigmata after the flowers were visited by butterflies and hawkmoth. These stigmatic pollen loads are suggestive of the role of lepidopterans in the pollination of *Duranta repens* flowers.

ix) *Breeding systems*: Bagging experiments ruled out the presence of apomixis and autogamy. Out of the 50 flowers pollinated with geitonogamous pollen, 58% resulted in fruit set. The 50 flowers pollinated with xenogamous pollen gave 68% fruit set. In both cases, seed set was 100%. Thus xenogamy appears to be relatively more successful in this taxon.

x) *Natural fruit set:* In open pollination 37% fruit set was observed. Seed set and fecundity was 100% each.

DISCUSSION

The flowers are hermaphrodite and homogamous. They are compatible with geitono-and-xeno pollen only. The flowers open at any time of the day. They are tubular (13 mm long) with a flat rim, always orienting upwards. They are visited during daytime by a number of insect species that included bees, a wasp, a hawkmoth and butterflies. The visitors are suitably rewarded with nectar and in case of bees pollen also formed part of the forage. These insects possess relatively long nectar collecting organs, namely tongues (bees and wasp) and proboscids (moth and butterflies) which enable them to manipulate the tubular corollas of *D. repens.* Further, the upward facing flowers with flat rims facilitated convenient landing of the foragers. The narrow tube with epipetalous stamens and introrse anthers facilitate the deposition of pollen on the proboscis of the foragers. Nine species out of the 30 species of foragers, namely the bees *A.c. indica,*

TABLE 5
POLLEN AMOUNTS IN BODY-WASHINGS OF DOMINANT FORAGERS ON *D. repens*

Name of the forager	Sample size	No. of pollen	
		Range	Mean
Apis cerana indica	5	27-66	51.0
Ceratina sp.	5	25-58	42.0
Amegilla sp.	5	35-62	57.0
Thyreus histrio	5	25-57	42.0
Danaus chrysippus	5	9-15	13.0
Atrophaneura hector	5	10-19	14.0
Papilio polytes romulus	5	10-25	19.0
Graphium agamemnon	5	13-33	19.0
Catopsilia crocale pomona	5	8-17	12.0
C. pyranthe	5	8-13	10.0

Amegilla sp., the diurnal moth *Macroglossum gyrans,* and the butterflies *Danaus chrysippus, Papilio polytes, Graphium agamemnon, Atrophaneura hector, Catopsilia crocale pomona, C. pyranthe* were constant and more frequent at all sites studied (Table 2). Of these *Amegilla, M. gyrans, P. polytes, G. agamemnon* and *A. hector* visited the flowers in rapid succession in short time (Table 3). They carried sufficient numbers of pollen on their proboscids (Table 5) and could transfer enough number of pollen on the stigma in their first visit (Table 4). Based on these observations they can be considered as the major pollinators of *D. repens.* Other foragers can also effect pollination, but their lower frequency of visits inconsistency, categorise them as minor pollinators.

The pollination that results from insect-visits may be geitonogamous and/or xenogamous. Foragers such as *Amegilla* sp., *Macroglossum gyrans,* the papilionid butterflies, and *Xylocopa* made frequent inter-population visits and could carry out xenogamous pollinations to a larger extent. In fact, xenogamy is a more successful mode of reproduction in this taxon.

An examination of the daily timing of foraging activity revealed that *Macroglossum gyrans* tended to avoid high temperatures by restricting its foraging time to the morning (0600-0800 hr) and to the evening (1600-1800 hr) hours. It appears that the

TABLE 6
POLLEN-DEPLETION FROM ANTHERS *vs.* POLLEN-DEPOSITION ON STIGMAS OF *D. repens* UNDER FORAGERS ACTIVITY

Daily time (h)	No. of pollen depleted/ flower	Rate of pollen depletion (%)	No. of pollen deposited per stigma	Rate of pollen deposition (%)
0800	1180	31	64	25
1000	1040	27	53	21
1200	620	16	47	19
1400	560	14	33	13
1600	210	5	23	9
1800	250	7	30	13

foraging activity of *M. gyrans* is conditioned by weather factors as no such staggered activity was seen on a cloudy day.

Though opened flowers of *D. repens* are available all through the day no nocturnal visitors were noticed in the study area.

D. repens flowers are bluish in colour and are abundantly visited by butterflies. According to Baker *et al.* (1983), the butterfly flowers range from white to yellow, pink and even red, but not blue. Ilse and Vaidya (1956) stated that butterflies show a preference for blue colour. Not only the colours of *D. repens,* but other blue flowers of *Hyptis suaveolens* and *Stachytorpheta indica* in this locality are frequently and abundantly visited by butterflies. Our finding corroborates the views of Ilse and Vaidya but not Baker *et al.* The sucrose and amino acid rich nectar of *D. repens* comes under the category of nectars that are preferred by butterflies.

It may, therefore, be concluded that *Duranta repens* flowers are primarily meant for butterfly pollination. Next to butterflies the hawkmoth *M. gyrans* and the wild bees *Amegilla* sp. may be considered as the most effective users of *D. repens* floral resource in a mutualistic way.

ACKNOWLEDGEMENTS

The senior author thanks R.E. Schultes, Botanical Museum of Harvard University, Cambridge, Massachusettes for his critical

comments, and also Dr. E.U.B. Reddy, scientist, Dept. of Environmental Sciences, Andhra University, Waltair for his constant encouragement and valuable suggestions.

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